DOCUMENT RESUME

ED 264 091 SE 046 240

AUTHOR	Bebout, Harriett C.; And Others
TITLE	MATHBOXES: A Program for the Apple II to Teach Children to Solve Basic Word Problems. A Report from the Project Using the Microcomputer to Teach Problem-Solving Skills. Program Report 85-5.
INSTITUTION	Wisconsin Center for Education Research, Madison.
SPONS AGENCY	National Inst. of Education (ED), Washington, DC.
PUB DATE	Sep 85
GRANT	NIE-G-84-0008
NOTE	26p.; Computer disc that accompanies this document is not available from EDRS.
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Addition; *Computer Software; Elementary Education; *Elementary School Mathematics; Mathematics Education; *Mathematics Instruction; Microcomputers; Numbers; Problem Solving; *Subtraction; *Word Problems (Mathematics)
IDENTIFIERS	Apple II

ABSTRACT

This manual is used with MATHBOXES, a computer program written for Apple II microcomputers to help children relate formal mathematical symbols for representing simple word problems to the informal strategies using physical objects that they naturally use to solve them. There is a substantial body of research that documents that young children are capable of solving a variety of simple addition and subtraction word problems by directly representing the action or relationships in the problems with physical objects. However, when they are introduced to formal mathematical symbols, they fail to see the connection between the manipulations they learn for these symbols and the informal strategies they use to solve the problem. MATHBOXES is designed to help children make this connection. The manual includes an overview of the program and directions for using it, discussing the various program options: (1) no numerals; (2) numerals only; (3) numerals and text (with additional choices for canonical-small numbers, canonical-large numbers, missing addend-small numbers, missing addend-large numbers, noncanonical-small numbers, or noncanonical-large numbers); and (4) leaving the program. (JN)

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Program Report 85-5

MATHBOXES

A PROGRAM FOR THE APPLE II TO TEACH CHILDREN TO SOLVE BASIC WORD PROBLEMS

by

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A Report from the Project Using the Microcomputer
to Teach Problem-Solving Skills

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September 1985

The research reported in this paper was funded by the Wisconsin Center for Education Research which is supported in part by a grant from the National Institute of Education (Grant No. NIE-G-84-0008). The opinions expressed in this paper do not necessarily reflect the position, policy, or endorsement of the National Institute of Education.

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Manual for MATHBOXES

Overview

MATHBOXES is a program written for the Apple II computer to help children relate formal mathematical symbols for representing simple word problems to the informal strategies using physical objects that they naturally use to solve them. There is a substantial body of research that documents that young children are capable of solving a variety of simple addition and subtraction word problems by directly representing the action or relationships in the problems with physical objects. However, when they are introduced to formal mathematical symbols, they fail to see the connection between the manipulations they learn for these symbols and the informal strategies they use to solve the problem. MATHBOXES is designed to help children make this connection.

Children initially are taught to use the microcomputer to solve simple word problems using the same strategies that they use with physical objects. They produce sets of objects one at a time by pushing the arrow keys. They can make one set, or make two sets, or remove elements from a set they have constructed. The objectives of these initial activities are to familiarize children with the microcomputer and to help them make the transition from using concrete objects to using the pictorial display.

The connection between the informal modeling strategies and the formal mathematical symbolic representations is made by teaching the children that they do not have to construct sets on the microcomputer one element at a time; they can construct them by writing number sentences. To solve an addition problem, they enter an addition sentence such as 8 + 5 = □ . Along with a number sentence, this entry produces two sets of boxes, a set of 8 and a set of 5, just as the child would using physical objects or the arrow key on the computer. Entering a subtraction sentence 13 - 8 = □ produces a set of 13 and then removes 8 elements to another portion of the screen. Since the number sentence that the children enter actually constructs the pictorial representation that they can use to solve the problem, writing the number sentence becomes part of the solution process and not an unrelated activity. Figure 1 illustrates the video display resulting from entry of the sentence 7 + 28 = □ .

The program also allows children to represent problems with noncanonical number sentences (e.g., 8 + □ = 13, □ + 5 = 13, 13 - □ = 8, □ - 5 = 8). This capability allows children to directly represent problems with a sentence that parallels the way they naturally think about and attempt to solve certain verbal problems. This noncanonical capability also offers students a means to represent and solve some of the more complex types of problems that young children generally cannot solve. This feature of the program has the potential to facilitate children's transition to more advanced levels of addition and subtraction concepts in which children are not limited to concrete modeling of problem situations but can symbolically represent problems as a means of solving.

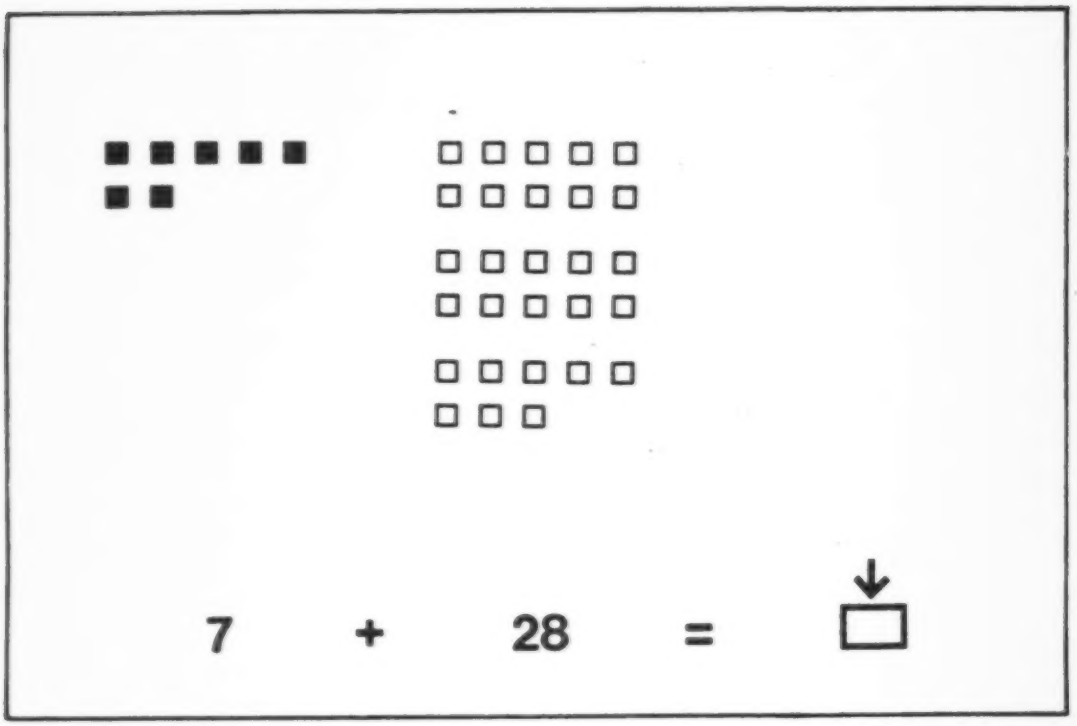

Figure 1. Video screen display after entry of 7 + 28 = □ .

Directions for Use of MATHBOXES

Materials necessary for MATHBOXES include an Apple IIe or 64K Apple II+, disk drive, monitor, and BOXES disk. After placing the BOXES disk in the disk drive and turning on the power, the following video displays appear:

WELCOME TO MATHBOXES

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MATHBOXES

Teacher's Menu

(1) No Numerals

(2) Numerals Only

(3) Numerals and Text

(4) QUIT

( ) Enter your choice.

You may return to this menu at any time by hitting both the CTRL key and "Q" simultaneously, followed by RETURN.

The user may now enter the option desired. Each of these options are described briefly below with fuller descriptions following in the text.

(1) No Numerals (boxes only). The screen displays only boxes according to the number of times the right arrow key is pressed or according to the numeral key typed.

(2) Numerals Only (boxes and symbols). When appropriate keys are typed, the screen displays both boxes and the symbolic number sentence, consisting of numerals, operation and equals signs, and an empty box for the unknown.

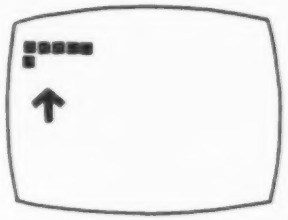
(3) Numerals and Text (boxes, symbols, and text). The screen initially displays a verbal problem. The problem can be represented by typing a number sentence that will generate boxes and the symbolic number sentence.

(4) QUIT. The screen displays the option offered by the USCD Pascal operating system.

To leave the program, the user should remove the disk from the disk drive (only when red light on disk drive is OFF), place the disk in protective sleeve, and turn off the power.

Option (1): No Numerals

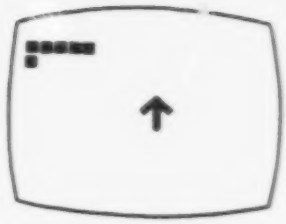
With this option, a child can generate two sets of boxes that can be used as counters to represent and solve canonical addition and subtraction problems. These two sets appear in different sectors of the screen, blue boxes in the left sector and green boxes in the middle sector. A maximum of 30 boxes can be entered in each sector; these are displayed in rows of 5's and double rows of 10's to make counting the total easier for the student.



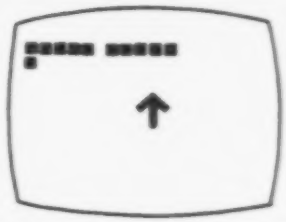
When this option is chosen, the cursor arrow appears midscreen pointing up at the left sector. Boxes are produced by pressing the right arrow key the desired number of times or by typing the numeral and pressing the return key. Boxes are erased from a sector by pressing the left arrow key.

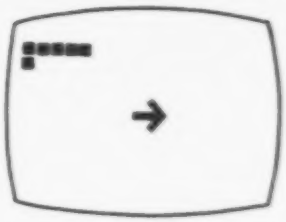
With boxes displayed in the left sector, addition and subtraction are

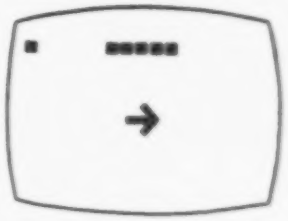
performed by the user in different ways. Addition is indicated to the program either by pressing the spacebar or by typing the plus sign. After one of these keys has been depressed, the cursor arrow appears midscreen pointing up at the middle sector. The second set of boxes is entered by pressing the right arrow key the desired number of times or by typing the numeral and pressing the return key. The indicated number of boxes appears in the middle sector. Boxes are erased from the middle sector by pressing the left arrow key.



Subtraction is indicated to the program by typing the minus sign. This keystroke causes a horizontal arrow to appear between the left and middle sectors. At this point, boxes are removed from the initial set by pressing the right arrow key the desired number of times or by typing the numeral followed by the return key. This causes boxes to move from the first set in the left sector to the second set in the middle sector. Boxes are removed by pressing the left arrow key. This action causes boxes to move back to their original position in left sector.







To erase the screen to prepare for another problem, the escape key (ESC) is pressed.

Glossary of Keys

[→]	right arrow key adds boxes to a sector one at a time, or moves boxes from the left sector to the middle sector following a minus sign
[←]	left arrow key erases boxes from a sector one at a time, or moves boxes from the middle sector to the left sector following a minus sign
[N] (0-30) with [RETURN]	numeral keys followed by the return key produce boxes in the left and middle sectors and provide the answer in the right sector
[+]	plus sign moves cursor arrow from left sector to middle sector and prepares the program to display boxes in the middle sector

[-]	minus sign moves cursor arrow from left to middle sector and prepares the program to move boxes from the left sector set to the middle sector
[SPACEBAR]	spacebar moves cursor to the next sector
[X]	X key erases a sector
[ESC]	escape key erases entire screen
[CTRL] [Q] with [RETURN]	control key and Q pressed simultaneously and followed by the return key erases screen and returns to the Teacher's Menu

Option (2): Numerals Only

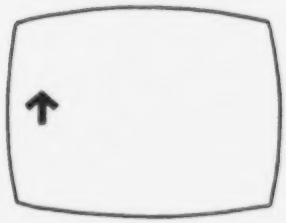
This option displays the mathematics problem in two modes, a pictorial mode consisting of boxes in the upper sector and a symbolic mode consisting of a number sentence in the lower sector. Problems are represented in both modes by typing number sentences.

A special feature of Option (2): Numerals Only is the program's capability for accepting open sentences with the unknown in any of the three sectors. With this feature, six types of open sentences can be entered: A + B = □ , A - B = □ , A + □ = C, A - □ = C, □ + B = C, and □ - B = C. After the open sentence has been entered, the child can return to the sector containing the unknown and can add or remove boxes to solve the open sentence.

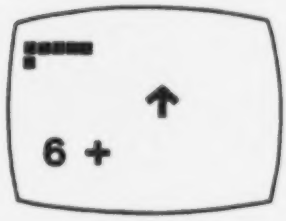
Open Sentences of the Types A ± B = □

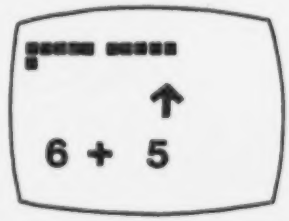
The operation of MATHBOXES for open sentences of the types A ± B = □ is similar to the operation described in Option (1): No Numerals, except that a number sentence is displayed along with the box configurations.

When this option is chosen, the cursor arrow appears midscreen pointing up at the left sector. Boxes with a corresponding numeral are produced by pressing the right arrow key the desired number of times or by typing the numeral and pressing the return key. Individual boxes are erased and the number reduced by pressing the left arrow key. All boxes in a sector are erased by typing X.

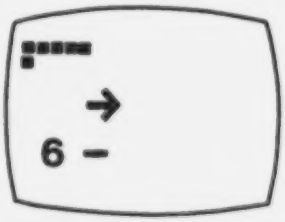


Addition is indicated to the program by typing the plus sign. The cursor arrow appears midscreen pointing up at the middle sector. The second set of boxes and a numeral are entered by using the same procedures as for the first set, by pressing the right arrow key a certain number of times or by typing the numeral and pressing the return key. Again, boxes corresponding to the numeral appear when the return key is pressed. Boxes are erased and the number reduced accordingly by pressing the left arrow key.

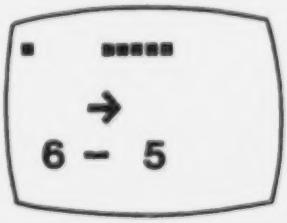




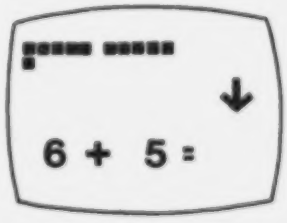
Subtraction is indicated to the program by typing the minus sign. A horizontal arrow appears midscreen between the boxes display and the number sentence.

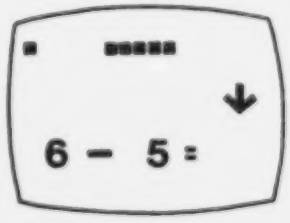


Boxes are moved from the initial set to the middle sector by pressing the right arrow key the desired number of times or by typing the numeral followed by the return key. This causes boxes to move from the initial set in the left sector to the second set in the middle sector. The left arrow key causes the boxes to move back to the left sector.

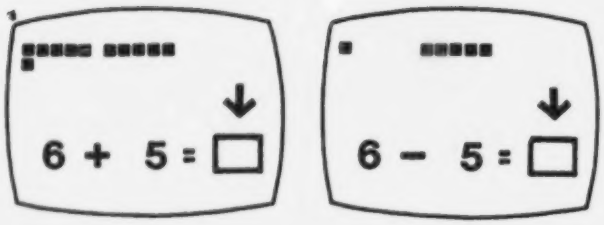


For both addition and subtraction, the equals sign is produced by typing an equals sign.





With the two numerals and the operation and equals signs entered, the box signifying the unknown is entered by typing a question mark. Pressing the return key produces the cursor arrow that points down at the empty box.



The answer is entered by pressing the right arrow key the desired number of times and pressing the return key or by typing the numeral and pressing the return key. To check the answer, the spacebar is pressed twice. If the answer is correct, the program responds with a beeping sound and the screen is cleared for the next problem. If the answer is incorrect, the program responds with a buzzing sound and the following message appears on the screen:

Sorry, your answer is incorrect.

Please hit X to try again.

The user is permitted to try four more times (5 times in all) before the following final message appears:

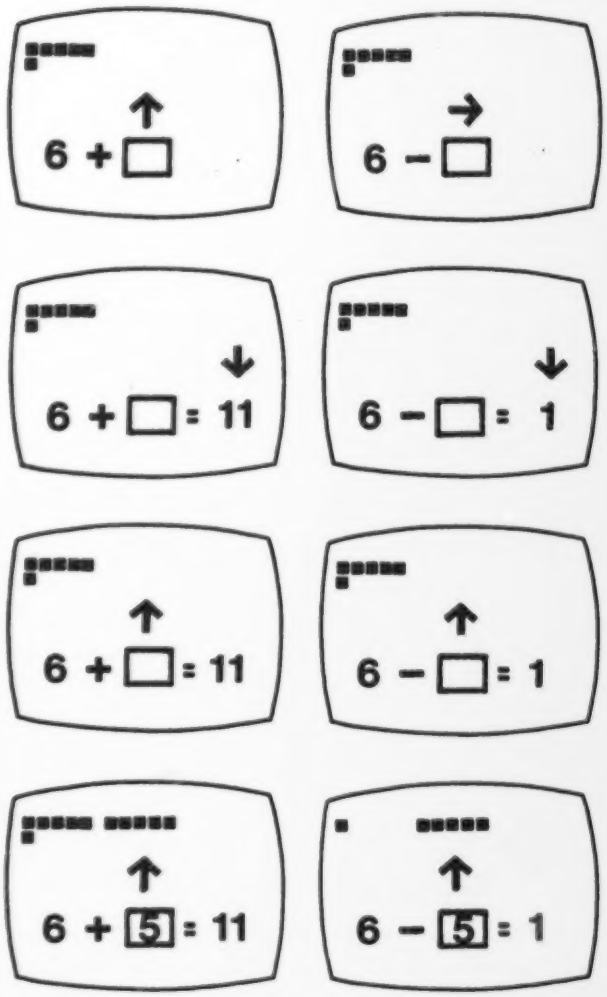
Sorry, your answer is WRONG.

The screen is automatically cleared by the program allowing the user to enter the next problem.

Open Sentences of the Types A ± □ = C

For open sentences of the types A ± □ = C, boxes and a numeral are produced in the left sector by pressing the right arrow key the desired number of times or by typing the numeral and pressing the return key. The operation sign, plus or minus, is then indicated to the program; a plus sign is produced by typing a plus sign. A minus sign is produced by typing a minus sign.

With the left sector numeral and operation sign displayed, the unknown element is entered by typing a question mark. The question mark produces an empty box as part of the number sentence display but leaves empty the upper box configuration area of the middle sector. Next an equals sign is entered. A numeral can be entered or the right arrow used to complete the open sentence. No boxes appear in this right sector. Pressing the spacebar returns the cursor to the empty sector, in this case the middle sector. The answer is entered by means of the right arrow or the numeral keys. If the operation indicated is addition, new boxes appear in correspondence with the numeral; if subtraction, boxes will move from the left sector to the middle to correspond with the numeral.



The answer is finalized by pressing the return key. To check the answer, the spacebar is pressed twice. If the answer is correct, the program responds with a beeping sound and the screen is cleared for the next problem. If the answer is incorrect, the program responds with a buzzing sound and the following message appears on the screen:

Sorry, your answer is incorrect.

Please hit X to try again.

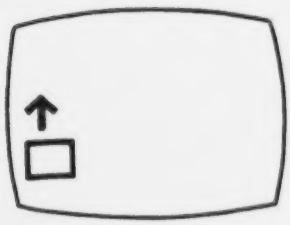
The user is permitted to try four more times (5 times in all) before the following final message appears:

Sorry, your answer is WRONG.

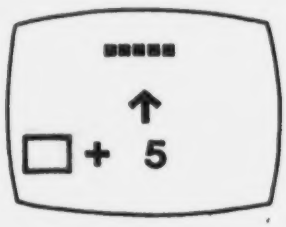
The screen is automatically cleared by the program allowing the user to enter the next problem.

Open Sentences of the Types □ ± B = C

For open sentences of the types □ ± B = C, the unknown is entered in the left sector of the screen. This empty box is produced by typing a question mark and pressing the return key.

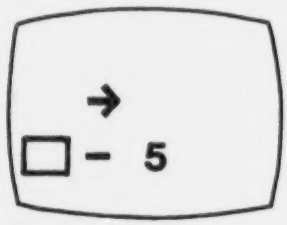


Addition is indicated to the program by typing the plus sign. The second addend is entered by using the same procedure previously described, by pressing the right arrow key or by typing the numeral. If the right arrow is used to produce the second addend, boxes appear in the upper middle sector with a corresponding numeral in the number sentence. If a numeral is typed to produce the second addend, the boxes do not appear until the return key has been pressed. Boxes are erased from the middle sector by pressing the left arrow key prior to pressing the return key.

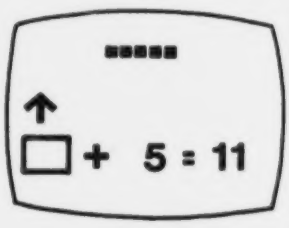


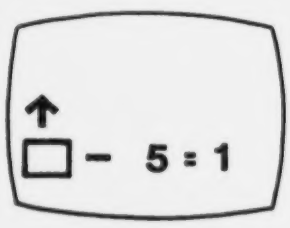
Subtraction is indicated to the program by typing a minus sign. A horizontal arrow appears over the minus sign in the display pointing to the middle sector.

The subtrahend is entered by pressing the right arrow key the desired number of times or by typing the numeral. In this option with an unknown starting a subtraction sentence, a numeral appears in the middle sector number sentence area but the boxes do not appear until the solution stage of the program. The number in the subtrahend may be reduced by using the left arrow key before the return key is pressed.



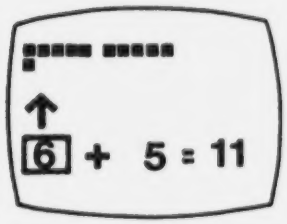
For both addition and subtraction, the equals sign is entered next. The final element of the number sentence is entered by pressing the right arrow key or by typing the numeral. Pressing the spacebar returns the cursor to the sector of the sentence containing the unknown, in this case the left sector.

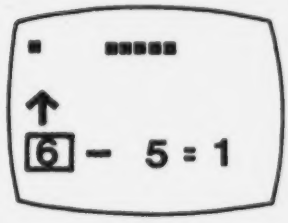




The solution is entered by pressing the right arrow key followed by the return key to produce boxes with a corresponding numeral or by typing the numeral followed by the return key. Pressing the spacebar finalizes the numerical entry.

For addition sentences, the boxes appear in the upper left sector as usual. For subtraction sentences, the boxes move from the left sector to the middle sector until the subtrahend number is reached; then the boxes appear in the left sector.





To check the answer, the spacebar is pressed twice. If the answer is correct, the program responds with a beeping sound and the screen is cleared for the next problem. If the answer is incorrect, the program responds with a buzzing sound and the following message appears on the screen:

Sorry, your answer is incorrect.

Please hit X to try again.

The user is permitted to try four more times (5 times in all) before the following final message appears:

Sorry, your answer is WRONG.

The screen is automatically cleared by the program allowing the user to enter the next problem.

Glossary of Keys

	right arrow key adds boxes to a sector one at a time, or moves them from the left sector to the middle sector following a minus sign
	left arrow key erases boxes from a sector one at a time, or moves boxes from the middle sector to the left sector following a minus sign
N (0-30) with RETURN	numeral keys followed by the return key produce boxes in left and middle sectors and provide the answer in the right sector
+	plus sign moves cursor arrow from left sector to middle sector and prepares the program to display boxes in the middle sector
-	minus sign moves cursor arrow from left to middle sector and prepares the program to move boxes from the left sector to the middle sector
=	equals sign prepares the program to accept the result of the addition or subtraction number sentence
?	question mark produces an empty box to mark the unknown in the number sentence
SPACEBAR	spacebar moves cursor to the next sector or to the sector with the unknown.
SPACEBAR SPACEBAR	spacebar pressed twice after correct answer causes screen to clear and enables user to enter next problem.
X	X key erases a sector
ESC	escape key erases entire screen
CTRL Q with RETURN	control key and Q pressed simultaneously and followed by the return key erases screen and returns to the Teacher's Menu

Option (3): Numerals and Text

General Discussion

This option displays a verbal problem and permits the user to solve the verbal problem by producing a pictorial boxes display or by writing a symbolic mathematics number sentence. Option (3) is operated in essentially the same manner as Option (2), except that the text of the verbal problem is displayed in the lower third of the screen. The user reads the verbal problem and solves the problem by using the pictorial or symbolic mode for solution. Figure 2 shows the video screen display for a sample verbal problem.

A special feature of this option is that the program will accept the unknown in any of the three sectors, A, B, or C, corresponding to the three number sentence parts, A ± B = C. This program capability permits the user to vary the position of the unknown according to the underlying mathematical structure of the verbal problems. For example, the following problem illustrates the rationale for permitting this capability:

> Polly has 3 stickers.
> Joe gave her some more.
> Now she has 8 stickers.
> How many did Joe give her?

When children solve this problem with concrete items, they appear to attend to the problem structure by setting out 3 items, adding on to these items until a set of 8 items is reached, and then counting the number of items added on to determine the solution of 5. This adding on action may be most nearly symbolically represented by the noncanonical number sentence 3 + ☐ = 8.

Many initial programs of mathematics instruction teach only the canonical number sentence form of 8 - 3 = ☐ to symbolically represent this problem, but research on children's informal solutions indicates that the noncanonical number sentence 3 + ☐ = 8 may be a more understandable symbolic representation for young children because it more nearly matches children's informal strategy of Adding On.

Thus, an important criterion in planning MATHBOXES was the capability of the program to accept several correct number sentences that result in the correct answer. For example, the four following number sentences are acceptable to the MATHBOXES program to symbolically represent this problem:

8 - 3 = ☐
3 + ☐ = 8
☐ + 3 = 8
8 - ☐ = 3

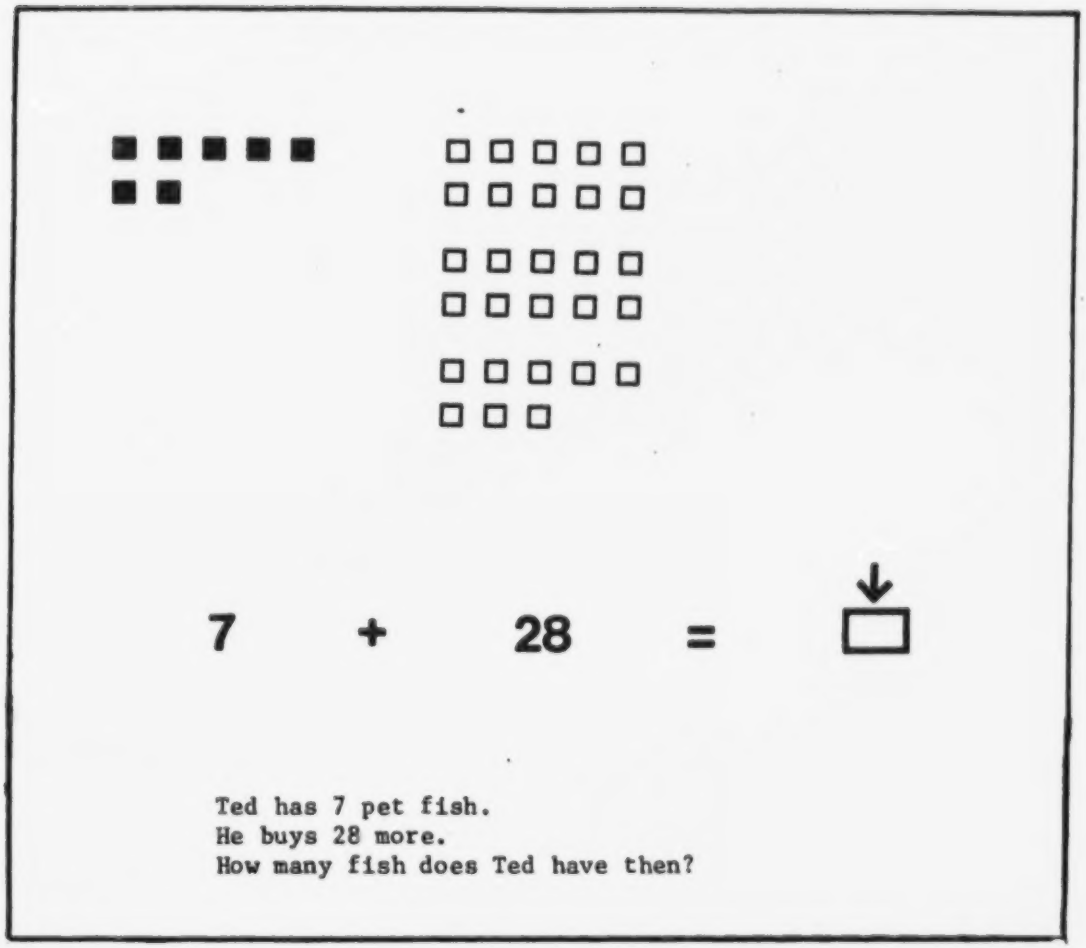


Figure 2. Sample video screen display for Option (3): Numerals and Text.

Verbal Problem Sets

When Option (3): Numerals and Text is selected from the Teacher's Menu, six choices of verbal problem sets are offered. Each set contains 20 verbal problems. The Small Number sets offer verbal problems based on the basic facts with sums less than 20; the Large Number sets offer verbal problems with at least one number between 20 and 30 in the number triplet.

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MATHBOXES

Teacher's Menu

(1) Canonical, Small Numbers

(2) Canonical, Large Numbers

(3) Missing Addend, Small Numbers

(4) Missing Addend, Large Numbers

(5) Noncanonical, Small Numbers

(6) Noncanonical, Large Numbers

( ) Enter your choice.

You may return to this menu at any time by pressing both the CTRL key and "Q" simultaneously, followed by RETURN.

(1) Canonical, Small Numbers, and
(2) Canonical, Large Numbers.

These two sets of verbal problems include simple addition and subtraction problems of the canonical forms A + B = ☐ or A - B = ☐. Examples of these problems are shown in a classification of verbal problems in Table 1 as Change 1 and 2 problems.

(3) Missing Addend, Small Numbers, and
(4) Missing Addend, Large Numbers.

These two sets of verbal problems include four structurally different types verbal problems classified in Table 1 as Change 1, 2, 3, and 5 verbal problems. Change 1 and 2 problems are simple addition and subtraction problems of the canonical forms A + B = ☐ and A - B = ☐. Change 3 and 5 problems are missing addend problems of the respective noncanonical symbolic forms A + ☐ = C and ☐ + B = C, respectively.

(5) Noncanonical, Small Numbers, and
(6) Noncanonical, Large Numbers.

These two sets include verbal problems of all six classifications exemplified in Table 1. Each verbal problem type is based on a different underlying mathematical structure: Change 1 and 2 have the forms A + B = ☐ and A - B = ☐ respectively, Change 3 and 4 have the forms A + ☐ = C and A - ☐ = C, and Change 5 and 6 have the forms ☐ + B = C and ☐ - B = C.

After selecting Option(3): Numerals and Text from the Teacher's Menu and after choosing one of the six problem set choices, a verbal problem is displayed in the lower portion of the screen (see Figure 2). The specific keystroke instructions for pictorial and symbolic inputs are the same as those presented in Option (2). Keystrokes specific to Option (3) are presented in the glossary at the end of this section.

The spacebar is important to the program's assessment of answers. Pressing the spacebar once enters the user's answer; if the answer is correct, the program makes no response until the spacebar is hit a second time; if the answer is incorrect, the program responds immediately with an error message.

When all the problems in a set have been completed, the Teacher's Menu reappears.

Table 1

Classification of Simple Change Type Verbal Problems

CHANGE	
Join	Separate
1. Connie had 5 marbles. Jim gave her 8 more marbles. How many marbles does Connie have altogether?	2. Connie had 13 marbles. She gave 5 marbles to Jim. How many marbles does she have left?
3. Connie has 5 marbles. How many more marbles does she need to have 13 marbles altogether?	4. Connie had 13 marbles. She gave some to Jim. Now she has 8 marbles left. How many marbles did she give to Jim?
5. Connie had some marbles. Jim gave her 5 more marbles. Now she has 13. How many marbles did Connie have to start with?	6. Connie had some marbles. She gave 5 to Jim. Now she has 8 marbles left. How many marbles did Connie have to start with?

Glossary of Keys

[→]	right arrow key adds boxes one at a time to sectors A and B or, after the minus key has been typed, moves boxes from sector A to sector B
[←]	left arrow key erases boxes one at a time from sectors A and B, or after the minus key has been typed, moves boxes from sector B back to sector A
[N] with [RETURN]	numeral keys (0-30) followed by the return key produce boxes in the A and B sectors and provide the answer in the sector containing the unknown
[+]	plus sign moves the cursor from sector A to sector B and prepares the program to produce boxes in sector B
[-]	minus sign moves the cursor from sector A to sector B and prepares the program to separate boxes from sector A to sector B
[=]	equals sign moves cursor from sector B to sector C and prepares the program to accept entry into sector C
[?]	question mark produces an empty box in the number sentence to mark the unknown in sectors A, B, or C
[SPACEBAR]	spacebar moves the cursor to the next sector to the right or to the sector marked by the unknown; after an answer has been entered, spacebar calls up program assessment; after a correct answer, spacebar calls up the next verbal problem
[X]	X key erases a sector
[ESC]	escape key erases entire screen
[CTRL] [Q] with [RETURN]	control key and Q pressed simultaneously and followed by the return key erases screen and produces the Teacher's Menu

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